TEMPERATURE AND HUMIDITY OF THE UPPER AIR AT SAN DIEGO, CALIF.

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Abstracted by L. T. Samuels

For the past three years the Naval Aerological Observatory at San Diego has been making free-air observations of temperature and humidity by means of airplanes. These observations were inaugurated primarily in order to determine densities aloft in connection with fleet target practice. It was soon decided, however, to continue the flights both for additional information with regard to the upper air and also to determine their value, if any, in relation to weather forecasting.

The instrument (aerograph) is suspended between the wings of a plane and a graphical record obtained of temperature, humidity, and pressure. In addition, notes are made upon general weather conditions as observed from the air, cloud altitudes, visibility, etc. Wind directions and velocities are determined from simultaneous pilot balloon observations. The average altitude reached has been between 6,000 and 8,000 feet. The following excerpts are quoted from Lieutenant Wyatt's paper:

Perhaps the outstanding feature of the records obtained, other than their apparent value in forecasting, is the great inversions of temperature found to exist on practically every day of the summer season and on numerous occasions during the so-called winter season. During the months of June, July, August, and September, 1924, every flight made, except one in the month of August, showed an inversion of temperature, the magnitude of the inversion varying between approximately 10° and 20° F. The inversions were usually found to begin at an altitude between 1,200 and 2,500 feet above the surface and to extend through a layer approximately 2,000 to 3,000 feet through. Practically every flight made during those months showed an increase in relative humidity from the surface up to the start of the inversion of temperature, after which it fell rapidly. At no time did the inversion extend above 6,000 feet, and temperature had usually started to fall before 5,000 feet had been attained. Pressure distribution during these months showed continuous low or relatively low pressure over the Colorado Basin, no map showing a pressure greater than 29.90 inches. Temperatures reported from this region of low pressure were above 100° F. Winds aloft over San Diego during the times of these flights invariably showed a layer of winds with an easterly component a few hundred meters above the surface, or else very light winds to calm.

It has been noted that very frequently the upper limit of haze or fog or cloud marks the start of the inversion, visibility usually being considerably improved through and above the inversion of temperature. Practically every flight that shows an inversion of temperature and an increase in humidity with a decrease above, was made at a time when the southwest semipermanent area of low pressure was well developed.

Other flights made show no inversion of temperature and a low relative humidity at the surface decreasing from the surface upward. It has been found that when these conditions are present, the pressure distribution shows that the weather is under the control of high pressure over the Southwestern States, and from the facts in the case this is what one would naturally suppose from the theory that the atmosphere in a high-pressure area is descending.[1] In the record of the flight for November 28, 1924, no inversion was encountered, both temperature and relative humidity decreasing from the surface to the limit of the flight. Pressure distribution on that date shows a HIGH centered over northern Nevada and southern Idaho, Boise reporting a barometer reading of 30.60 inches, and a relatively steep pressure gradient existing to the northeast of San Diego. The records showing these characteristics also fall into a definite class of pressure distribution.

In another class are those records that show no inversion of temperature and either high relative humidity within the limits of the flight or an increase of humidity up to certain limits, and it is these records that have been of value in the forecasting of precipitation. The flight made on October 6, 1924, was the first flight made that showed these characteristics very definitely and precipitation occurred on the night of that date. The record of this flight shows that the sky was practically overcast with strato-cumulus clouds at an elevation of 5,000 feet. Temperature fell during the entire climb except when emerging through the cloud bank where a slight inversion occurred after which temperature continued to fall. Relative humidity increased from the surface upward except when passing through inversion of temperature. Pressure distribution on the morning of this date showed high pressure over the entire country east of the Rocky Mountains and a low pressure area centered at Tonopah, Nev., that station reporting a barometer reading of somewhat lower than 29.70 inches. During the night, the low-pressure area had moved somewhat to the southeastward and was centered at Flagstaff, Ariz., and the following morning relatively high pressure showed along the entire Pacific Coast.

The flight for December 17, 1924, shows no inversion and an increase in relative humidity with altitude and shortly thereafter precipitation occurred. Of 24 records showing these characteristics, 18 were followed by precipitation, usually occurring during the night following the flight.

Although there has been insufficient data collected upon which to form any definite conclusions, there seems to be no doubt of the value of the flights in regard to forecasting and it is hoped that with the additional collecting of data, many facts hitherto unknown will be made apparent and that knowledge of them will increase the percentage of verification of forecasting in this locality, particularly in regard to precipitation. Often when there has been a doubt as to whether to issue a rain or fair weather forecast, the writer has waited until after the aerographic flight was made and if the the record showed these characteristics, a rain forecast was issued and in only one case where the forecast was based upon the aerographic flight record was the forecast of precipitation a failure. During the month of February, 1924, when precipitation occurred on three successive nights with clearing weather during the day, the forecast of rain was issued solely upon the indications of the flight record and was verified 100 per cent for the storm.

[1] The latter half of this sentence was evidently written under misapprehension as to (1) the present view of the theory that the air in anticyclones is descending, and (2) the effect of a descent of air on its relative humidity.

(1) The idea is no longer held that there is an active descent of air in anticyclones except very locally along the fringes of the mass of cold air at the earth's surface, and even here the descent is through a small vertical extent. The great body of air settles with extreme slowness. Sir Napier Shaw has calculated the rate to be about 86 meters per day for the North Atlantic anticyclone, and for small anticyclones, 3 to 5 times as much. Hence as regards relative humidity changes, these must be controlled by factors other than adiabatic heating induced by descent.

(2) If anticyclonic air did actively descend, its relative humidity would decrease from top to bottom, not from bottom to top, obviously because adiabatic warming increases the capacity of air for water vapor.—B. M. V.

DEVELOPMENT AND PRESENT STATUS OF FROST-FIGHTING DEVICES

By FLOYD D. YOUNG

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Nearly nineteen hundred years ago the Romans were attempting to protect their vineyards from damage by frost by building smudge fires. This method is still in use in some parts of the United States, although careful experiments have demonstrated that a smoke cover alone affords little protection.

Apparently the first actual "orchard heating," as distinguished from "smudging," on the Pacific coast was carried on in orange groves near Riverside, Calif. during the years 1897–1899. Coal baskets made of large mesh heavy wire screen were set in the orchards at the rate of 40 baskets to the acre. Good results were obtained.

The use of oil-burning orchard heaters on a large scale appears to have begun about 1905. They were at first simply open pans, which gave off large quantities of black smoke and soot. Following the disastrous freeze in southern California in 1913, the "low-stack" oil heater came into more general use. The amount of smoke and soot was thus reduced somewhat, but combustion was still far from satisfactory.

Between 1915 and 1918 the so-called "high-stack" heater began to make its appearance. These heaters are more nearly smokeless than any other type that has been put on the market in commercial quantities. During a warm day, they will, with draft carefully regulated, burn with practically no smoke. But when hundreds or thousands are burning together on a cold night, with little or no careful regulation, considerable smoke results.

In 1917, when the Weather Bureau fruit-frost service was begun, orchard heating was in bad repute, due to the use of poor equipment, too few heaters to the acre, inaccurate thermometers, over-sleeping, etc. The acreage protected with heaters was decreasing from year to year, and the smoke problem was not acute except in one or two localities. During recent years, however, the protected acreage has increased by leaps and bounds. During the winter of 1924–25, there was so much orchard heating that considerable objection to the smoke and soot resulted.

The townspeople in fruit growing communities have been looking for improved smokeless methods of protecting the fruit, but they have not been working alone. Orchard heating is an extremely disagreeable chore at best. The grower therefore has a double incentive to develop some new method of frost protection. This is as it should be, if it were not for the fact that both growers and townspeople have been so eager for a solution of the problem that they have grasped at straws. Every new scheme has immediately gathered a host of enthusiastic supporters.

It has been the policy of the fruit-frost service to test each new device for frost protection as soon as it has been placed on the market Tests are made in the orchards and only on frosty nights, so that the result will be conclusive. We then make public our findings through talks at fruit growers' meetings, magazine and newspaper articles, and by correspondence in reply to written requests for information.

Early in 1920 we published a short paper showing that temperature inversion on most frosty nights in southern California is very strong. Immediately several inventors set to work to devise machines to keep the air mixed to a considerable height above the ground and prevent stratification. The problem appeared so simple that growers easily were led to believe the extravagant claims made by the inventors and their salesmen.

The first machine tested was very crude. It consisted of a horizontal fan with four blades 6 feet in length, placed on the top of a 15-foot tower and turned at the rate of about 100 revolutions per minute by a gasoline motor, to force down the warmer air lying above the orchard. Later, orchard heaters were placed in a ring about the base of the tower to further heat the descending air. The machine was a complete failure.

The second machine consisted of a centrifugal blower, connected to a vertical pipe the upper end of which was about 15 feet above the ground. An elbow at this upper end turned the stream of air horizontally outward. By rotating the pipe the air was discharged in any direction desired. As was to be expected, this machine also failed to accomplish it purpose.

It would have been a simple matter to demonstrate theoretically that neither of these machines had any hope of success, but a thorough field test was necessary to convince the growers. In spite of the wide publicity given the results of these tests a stock company was organized to manufacture and market the first machine, and several machines of the second type were actually sold. Fortunately the following winter was unusually cold and the purchasers soon were convinced that they had been misled.

The third machine (fig. 3) was erected for experimental purposes in a lemon grove by an association of fruit growers. A 15-inch sheet-iron pipe was placed upright, with its upper end 35 feet above the ground. Near its base a 40-inch centrifugal blower operated by a 20-horse power gasoline motor drew air down through the pipe to two outlets, one of which discharged it downward against the ground, the other throwing a current horizontally over the tops of the trees. The two outlets were used independently at different times. Two small oil burners were connected with the vertical pipe, so that the heated gases were drawn directly into the blower and mixed with the air brought down from the 35-foot level.

Some very interesting results were obtained with this machine. Without the furnaces in operation the temperature of the discharged air averaged 6° to 7° higher than air at the same elevation in the orchard. With the furnaces the temperature at the outlet was about 35° higher than in the orchard. The volume of air discharged was too small, however, to affect the temperature in the orchard appreciably, and when the furnaces were operated the warm air passed upward so rapidly that it soon was lost. Also it was not possible to force the air stream more than a few feet against the natural drift in the orchard.

The fourth machine tested was constructed on a rather heroic scale. It was built entirely of steel, on a concrete foundation, and was equipped with a six-cylinder, 120 horsepower gasoline motor geared to a vertical shaft turning at 700 revolutions per minute a four-bladed airplane propeller 40 feet above the ground. A large oil-burning furnace was set between the propellor and the ground to heat the descending air from the propellor. Perforated water pipes furnished a spray with which it was intended to increase the humidity of the air as it was driven downward and outward by the machine. The furnace consumed 80 gallons of fuel oil per hour, and the motor 10 gallons of gasoline.

The machine was set up in an orange grove of large and heavily foliaged trees. On the night of the most favorable test, the temperature was 30.1° in the orchard, and 36.6° at the edge of the apron below the propeller without the furnace being operated. The velocity of the air at this point was so great that it was practically impossible to breath. But there was no visible evidence of air movement farther than 120 feet to the northward. Toward the west, in the general direction of the natural air drift, the movement could be noted somewhat farther, but the effect on temperature was slight at a distance of more than 125 feet. The temperature 50 feet west of the machine was raised 5° without the furnace in operation, and 8° with the furnace. The failure of the machine was due to its inability to spread the heated air over a large enough area.

The fifth and latest "wind-jammer," (fig. 3) as these machines are called locally, is backed by almost unlimited capital. Some of the best known capitalists in California are said to be heavily interested in the corporation. The machine consists of a large diameter pipe in the form of a right angle, with the bottom of the vertical portion about 25 feet above the Ground, supported by an open framework. Below the lower end of the pipe is a large oil-burning furnace. A propeller set between the furnace and the pipe forces the products of combustion into the lower end of the pipe from the upper end of which they are discharged horizontally over the tops of of the trees at a height of about 35 feet above the ground. One machine is guaranteed by the manufacturers to furnish adequate protection for 10 acres. The first machine tested failed mechanically. Its effect on the temperature was negligible.

An all metal machine with a minimum number of parts was then designed, and a number of them were sold before they could be thoroughly tested. During the cold

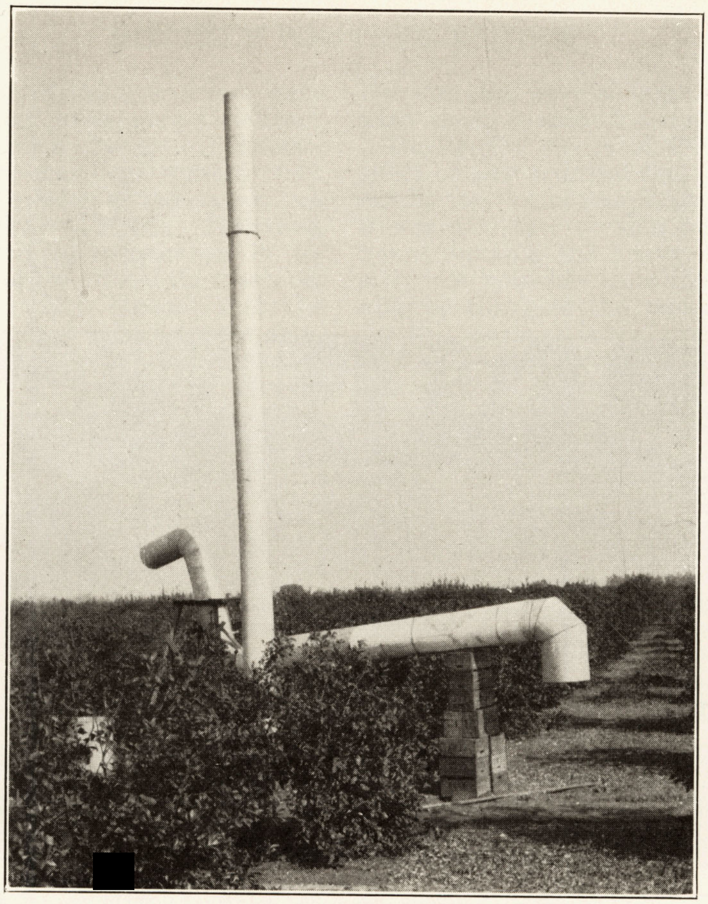

Fig. 1.—Machine developed to bring down warm air from above the orchards on frosty nights for distribution among the trees. Vertical galvanized sheet-iron pipe, 15 inches in diameter and 35 feet high

Fig. 2.—In this machine the airplane propeller, intended to bring down warm air from above the trees, is 40 feet above the ground. The "barrel" of the machine, below the roof, contains an oil-burning furnace, which heats the descending air

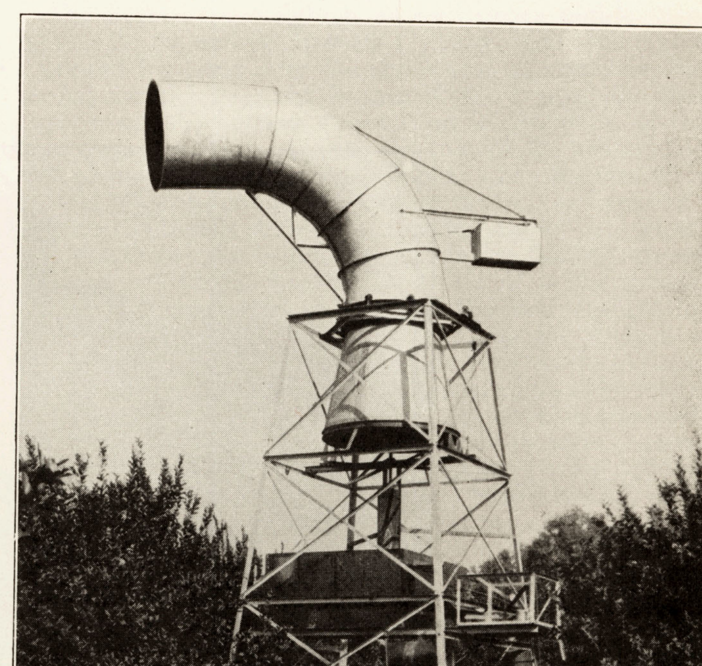

Fig. 3.—Latest type of machine designed to mix air strata on frosty nights, and thus to raise the temperature. An airplane propeller directly below the lower end of the large pipe throws a stream of air upward through it. An oil-burning furnace heats the air before it reaches the propeller. The discharge outlet of the pipe is about 35 feet above the ground

periods of December, 1924, two of these machines were given a careful test in a lemon grove near Pasadena, Calif. One broke down immediately because of the settling of the motor. The other was kept running only with difficulty, because of overheating of the motor, but it was operated throughout all the cold nights. It showed practically no effect whatever on the temperature in the orchard, even within a few feet of the base of the machine.

Following the earlier tests, which showed that the temperature in the orchard was not raised appreciably, the officials of the company had claimed that protection against freezing of the fruit was afforded regardless of temperature simply by creating a breeze over the trees. In the latest test, however, this contention was entirely disproved. The fruit crop was a total loss, and the trees were defoliated and severely damaged.

This corporation has spent probably several hundred thousand dollars in experimental work, without much encouragement. At present it appears that the method will be abandoned. The machines cost several thousand dollars each, and it is believed that by discouraging their purchase the Weather Bureau has been instrumental in saving the growers large sums of money.

Overhead sprinklers.—During the past two years several citrus growers have installed overhead sprinklers, for irrigation and frost fighting combined. Vertical pipes carrying the sprinklers at their tops are set at intervals which allow the entire grove to be sprayed.

From the beginning, we have done everything possible to prevent growers from counting on the efficiency of overhead sprinklers in protecting fruit from frost. Despite this, several large citrus groves were equipped with them, mainly for frost protection.

During the winter of 1924–25 a careful check on the effect of this artificial rain was made under actual frost conditions. The temperature was raised about 3°, but it was necessary to shut off the water after about two hours, because the heavy coating of ice threatened to strip the branches from the trees. We have thus been able to convince the growers that overhead irrigation for this purpose is not practical.

To describe all the new heaters tested would exceed the limits set for this paper. They may be briefly mentioned. First is the central heating plant. The fuel was burned in a large furnace, and the heated gases driven through large pipes through the orchard. Second is the covering of the trees with canvas tents. Third is the running of irrigation water in furrows in the orchard; this practice appears to have some value, but is effective only when the temperature does not fall much below the danger point. In a carefully conducted experiment, it was found that running water at a temperature of 72° in an orange grove held the temperature about 1.5° on the average above the outside temperature. Fourth is the use of coal briquets for orchard heater fuel. These were found to be satisfactory for protecting small acreages, but high labor charges and other drawbacks make their use inadvisable for large acreages.

To sum up the matter, the orchard heater is today the only practical means of obtaining complete protection from low temperatures in orchards, but constant effort is being directed toward finding some more satisfactory method.

VALUE OF SMUDGE-POTS IN PREVENTING FROST IN CRANBERRY BOGS

(Summary of a report by R. A. Wells and Perry Parker)

By Floyd D. Young

The Fruit-Frost Service of the Weather Bureau receives numerous inquiries regarding the practicability of using heaters to protect low-growing crops, such as strawberries, potatoes and tomatoes, from frost damage. Tests conducted recently by Mr. Roy A. Wells, in charge of the Weather Bureau office at North Head, Wash., and Mr. Perry Parker, his assistant, to determine the amount of the temperature rise that can be obtained by burning fuel oil in lard-pail heaters on the cranberry bogs near the mouth of the Columbia River, are of considerable interest in this connection. The flooding of the bogs for frost protection, as is done in Wisconsin and the Atlantic coast cranberry sections, is not practicable in Washington.

A one-half acre plot, equipped with forty 10-quart lard-pail oil heaters, was selected for the heating tests. The heaters are similar in shape to an ordinary lard pail, from which they take their name. They are 9 inches in height, with a top 9½ inches in diameter, and a bottom 8½ inches in diameter. The "spider" is a removable disk, which is placed over the top of the heater, reducing the rate of fuel consumption.

An instrument shelter was placed in the center of the plot, and another in a bog not equipped with heaters, about 300 feet distant, for a check on the outside temperature. Both shelters were set directly on the vines. The instrument shelter in the protected area was placed 15 feet from the nearest heater. Exposed thermometers were placed on the surface of the vines near both instrument shelters, for a check on the radiation temperature.

The heaters were lighted on two frosty nights, September 25–26, and October 10–11, 1924. On both nights a ground fog hung over the check plot at intervals, but no fog formed over the heated plot. During the first experiment the heaters were set on iron tripods, of the type shown in Figure 1, with the tops of the heaters 2½ feet above the surface of the vines. The heaters were burned with the so-called "soot arresters" or "spiders" in place, reducing the rate of burning about two-thirds. The maximum rise in temperature inside the instrument shelter, due to the heaters, was 2.9° F. The ground fog at the check station affected the temperature indicated by the thermometer exposed on the surface of the vines, so that a direct comparison between the exposed thermometer readings at the two plots can not be made. However, by comparing the difference between the readings of the sheltered and exposed thermometers in the area equipped with heaters before the heaters were lighted, with the difference while the heaters were burning, some conception of the effect of the direct radiation from the heaters on the temperature of the vines, may be obtained.

Before the heaters were lighted the average difference between the readings of the sheltered and exposed thermometers was 5.1° F. When the heaters were lighted the difference was reduced to 1.4° F., making a rise of 3.7° F. due to the heating. Adding the rise of 2.9° F. shown by the sheltered thermometer, to the 3.7° F. rise shown by the unsheltered thermometer, due to direct radiation from the heaters, a maximum effective rise in temperature at the surface of the vines of 6.6° F. is indicated. The average effective rise in temperature on this night was 5.1° F. at the surface of the vines.